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Review of Soviet Petroleum Industry Technology and Equipment

General Level of Technology

Petroleum industry technology and equipment in the USSR is basically similar to that developed in the US, but lags that of the west in all operations except perhaps in the transmission of crude oil and natural gas via extra large diameter pipelines. The areas of greatest US technical superiority lie in seismology and deep drilling, as well as, in the design and production of producing, processing, and pipeline installations.

A. Exploration methods in the USSR are similar to those developed in the US, but the Soviets are about 10 years behind the US in applied seismograph techniques and the ability to map deep drilling prospects. Soviet exploration for oil and gas utilizes all of the basic geophysical techniques, including seismograph, gravity meter and magnetometer surveys. Gravity and magnetic readings are widely used to delineate areas for seismograph prospecting. The accuracy of Soviet - Worden type - gravity meters is less than that of the US type instrument. The Soviets have been unable to make reliable quartz elements for their gravity meters and the difference in precision of readings is often critical. Gravity meters are essential for successful deep exploration of the salt dome - oil deposits in the Caspian embayment.

The great contrast in Soviet and US seismograph technology can be attributed to the lack of modern computer hardware and software and the obsolescence of receiving and recording equipment. The Soviets are deficient in the use and availability of magnetic tape and recording heads, digital and analog field recording equipment, computer playback centers for the processing of seismic records, and high quality geophones and seismic cable. The low quality geophones and cable prevent the reception of low frequency signals reflected from deep lying structures. Soviet geophones are reportedly underdamped and capable of receiving 20-33 cycles per second (CPS) signals; whereas 14.4 CPS are necessary for deeper exploration. The lack of computer gear precludes the display of variable density cross-sections and the ability to "stack", or integrate seismograms. The widespread application of computers to seismograph operations has developed in the US since 1963, and since then it has revolutionized deep petroleum exploration.

Soviet seismologists rely heavily on the "refraction" method for regional mapping of basement structure, and the "reflection" method for the final detailing of drilling prospects. In the West, far greater reliance is placed on "reflection" shooting in all seismic work due to the greater accuracy of deep records which are vital to the mapping of complex geological conditions. There is no evidence that the Soviets have developed weight dropping techniques like those used in the west (Vibroseis or Dinoseis) in areas of high seismic noise background. Sparker methods are similar to those used in the west in offshore waters in order to avoid the detonation of explosives and fish kill.

B. Deep drilling below 2500 meter depths represent the major "bottleneck" in the future expansion of crude oil and natural gas production. Potential petroleum reserves are large but increasing well depths and rising well costs, which normally account for about 40% of total oil and gas industry investment, could limit output. Deeper drilling in old producing regions could also obviate the construction of long distance pipelines which consume about 40% of total industry investment and the costly development of new West Siberian deposits of oil and gas.

Approximately, 85% of all the oil and gas wells in the USSR are drilled by the turbodrill method, about 13% by the rotary method, and the remainder by experimental techniques including the electrodrill and possibly percussion-rotary methods. Turbodrilling is exceptionally well suited for drilling in shallow (less than 2000 meter deep) hard rock formations like those encountered in the development of the Urals-Volga Region, but it is inefficient in the deeper soft rock formations found elsewhere. Rotary drilling is used about 99% of the time in the free world because it is much more efficient than turbodrilling below 2000 meter depths.

Turbodrilling differs from rotary techniques in that drilling fluids drive a downhole motor (turbine) and bit, while the drill pipe remains stationary. In rotary drilling, the entire drill column and the bit are rotated from the surface by motors. Slower rotational speeds, increased torque, and reduced axial loads and wear on bits and drill pipe represent the chief economic advantages of the rotary method. Shortages of high quality drill pipe and tri-cone bits limit the use of rotary drilling below 2500 meter depths in the USSR. The Soviets are also deficient in mud systems and in the technology of drilling fluid composition which adversely affects the penetration rates, bit life and turbodrill life.

C. Production methods in the USSR are similar to those used in the west, with one major exception. While developing the vast Urals-Volga oilfields in the post World War II period, the Soviets introduced the practice of water flooding new fields at the outset or primary reservoir drive mechanism has been exhausted and commences at the start of the secondary recovery phase of the production cycle. The widespread use of water floods to maintain reservoir pressures theoretically serves to increase ultimate reserves and recovery, and requires the drilling of a fewer number of high yield flowing wells. In practice, the Soviets ruin fields by uneven flooding when they overproduce flush wells in order to achieve production goals. When possible, natural gas reservoirs are repressured by recycling dry processed gas back into the producing strata with compressors, similar to US field procedure.

The area of greatest technical deficiency in production methods is the Soviets highly automated field equipment, high pressure well head units, centrifugal down hole pumps, and to produce two or more overlying reservoirs simultaneously, without the drilling of extra wells. The lack of equipment for processing condensate and associated gas at oil wells and the lack of sulphur removal installations are matters of increasing concern to Soviet production operations. Much of these by-products are currently wasted. About 12 billion cubic meters of associated gas was flared in 1970. Oil and gas well cementing techniques are also inadequate and improvement would reduce the amount of water contamination in producing zones.

D. Offshore technology in the USSR is far behind that developed in the US, and in use throughout most of the waters of the free world. Petroleum deposits located offshore in the Caspian Sea in water depths exceeding 40 meters have been inaccessible, except by directional drilling from either onshore locations, or by drilling from manmade offshore islands which are connected to the mainland by trestle supported roadways. The Soviets have very limited experience with floating jack-up type, drilling platforms. Until 1967, the "Apsheron" was the Soviets only offshore floating platform and it was limited to the drilling of shallow wells no more than 2000 meters deep in up to 20 meter water depths. In late 1967, the Soviets imported a modern offshore deep drilling platform, the "Khazar", at a cost of $10 million from the Netherlands. The Khazar should be able to drill 6000 meter wells in water depths of 60 meters. However, maintenance of the Khazar equipment may prove difficult and prevent optimal performance. The Soviets have indicated a need for 10 offshore platforms in the Caspian Sea, but only one, the "Azerbaidjan" is under construction at Baku. The import of additional platforms from western suppliers appears likely. The Khazar accounted for about 25% of total petroleum industry equipment imports in 1967. The US industry possesses hundreds of offshore drilling platforms which operate throughout the world and hold most operating records. In addition the US industry has pioneered and developed most of the intricate offshore support systems and related technology which permit the economic exploitation pipelining, and storage of offshore crude oil and natural gas.

E. The pipeline transmission of crude oil and natural gas through extra large diameter pipelines over great distances has reached its highest point of development in the USSR. The Soviets are currently laying oil and gas pipelines 48 and 56 inches in diameter which are over 1000 kilometers long; whereas, the largest linepipe used in the US is approximately 40-42 inches in diameter for relatively short distances. This experince has posed several interrelated technological problems, in construction equipment, in linepipe metallurgy and fabrication, in the design of pumping and compressor equipment, in remote control systems, and in valves. Pipeline construction costs currently account for about 40% of total petroleum industry investment.

Pipeline operations in the US are much more advanced in all other respects than those in the USSR and reflect a higher degree of technical sophistication and automation.

Equipment Supply and Imports

Petroleum industry equipment of all types is in short supply in the USSR, and quite often it is obsolete, or unreliable. The short supply and limited performance of basic oilfield equipment impinges on all phases of industry operations. In many instances, modernization of equipment could be achieved by further modification of existing types; however, in other instances the equipment needed may not be domestically produced, and has to be imported. Imports of petroleum industry equipment almost doubled between 1965 and 1967, reflecting greatly increased purchases of drilling equipment.

A. Exploration equipment requirements include magnetic tape and recording devices, computer hardware and software processing seismic records, well-logging equipment, and gravity meters. Seismic field operations would be greatly improved with the acquisition of digital and analog recording units (including related software) and improved geophones and seismic cable.

B. Soviet imports of deep drilling equipment reflect the domestic petroleum industry's greatest need. Drilling equipment deficiencies include standard rotary tools, offshore floating drilling platforms, tri-cone and diamond drill bits; high pressure mud pumps, well head fixtures, and blow-out preventers; high quality drill pipe, special tools and cementing equipment.

C. Production operations would benefit most from the acquisiton of automated producing equipment (Line Automatic Custody and Transfer Systems) multi-zone producing equipment, centrifugal down hole pumps, associated gas processing plants and low temperature seperation equipment. In addition, the Soviets need compressors; oilfield desalting and dewatering equipment for field processing of crude oil; and hermetically sealed storage tanks, which contain vapors and minimize evaporating losses. In the future, more automated and sophisticated producing equipment which can operate in arctic and permafrost conditions will be essential for development of the W. Siberian oil and gas deposits (special wellheads, pumps and valves gathering systems and tank batteries).

D. Pipeline transportation and construction have increased rapidly during recent years but achievements have fallen short of announce goals due to shortages of equipment. Acute shortages of large diameter linepipe, compressors, and valves, have necessitated imports, and reduced transmission efficiency and throughput capacity. Many pipeline failures have been reported as a result of low quality domestic steel pipes and valves. The Soviets now contemplate the use of the largest linepipe in the world, including 48", 80" and 100" sizes. In 1971-1975, the Soviets plan to construct 57,000 kilometers of oil and gas pipeline (vs 36,000 km during 1966-1970) which will require approximately 16 million tons of large-diameter pipe. The pipe requirements alone will probably exceed domestic output plus what has currently been planned for import by about 5 million tons. The corresponding requirements for large diameter valves, pumping and compressor equipment will also exceed present Soviet production capability.

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Estimated Total Consumption of Oil Products
(Million Metric Tons)

Year	USSR	Eastern Europe	Total
1958	86.7	12.0	98.7
1959	94.2	14.0	108.2
1960	102.7	16.0	118.7
1961	111.3	18.5	129.8
1962	124.2	21.0	145.2
1963	137.0	23.5	160.5
1964	146.8	26.0	172.8
1965	156.3	28.7	185.0
1966	166.8	31.7	198.5
1967	181.9	34.6	216.5
1968	193.8	37.5	231.3
1969	208	41	249

Military Consumption as % of Total Consumption

Year	USSR	Eastern Europe	Total
1958	16.7%	6.7%	15.5%
1959	14.8%	6.4%	13.7%
1960	11.1%	5.0%	10.3%
1961	10.4%	5.4%	9.8%
1962	7.1%	4.3%	6.7%
1963	6.6%	3.8%	6.2%

Estimated Military Consumption of Oil Products (Million Metric Tons)

Year	USSR	Eastern Europe	Total
1958	14.5	0.8	15.3
1959	13.9	0.9	14.8
1960	11.4	0.8	12.2
1961	11.7	1.0	12.7
1962	8.8	0.9	9.7
1963	9.1	0.9	10.0

Estimated Military Consumption of Jet Fuel (Million Metric Tons)

Year	USSR	Eastern Europe	Total
1958	8.6	0.4	9.0
1959	8.0	0.4	8.4
1960	7.3	0.4	7.7
1961	7.6	0.5	8.1
1962	5.3	0.4	5.7
1963	5.4	0.4	5.8

Military Consumption of Jet Fuel as % of Total Military Consumption of Oil Products

Year	USSR	Eastern Europe	Total
1958	59%	50%	59%
1959	58%	44%	57%
1960	64%	50%	63%
1961	65%	50%	64%
1962	60%	44%	59%
1963	59%	44%	58%

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Data on Soviet Hydrocracking

With the extensive demand for residual fuel oil in the USSR, there has been no widespread development of further processing heavy residuals, thus obviating the need for extensive introduction of catalytic cracking and hydrocracking of distillate fuel feedstocks. In 1967 it was planned to develop the technology of hydrocracking in the USSR to yield low sulfur diesel fuel and jet fuel, not to maximize gasoline output as in the U.S. A 2-stage system was being developed at the research level, but problems were experienced in the development of a stable, efficient catalyst. Development of such a catalyst was to be one of the main priorities of the All-Union Scientific Research Institute for Petroleum Refining. In 1968 it was expected that Soviet-built hydrocrackers would have a capacity of 300,000 tons/year and at a later date would be built with a capacity of 600,000 tons/year. Plans for the future call for a typical Soviet refinery to have a crude oil charge of 12 million tons/year and include catalytic reforming, hydrocracking, and hydrogen treating.

In early 1969 a Soviet journal reported that several techniques for hydrocracking distillate raw material in 1 or 2 stages at pressures ranging from 50 to 150 atmospheres (735 to 2200 psi) had been developed.

1. Data were compared for processing 900,000 tons of vacuum gas oil 1) by single-stage hydrocracking at 50 atm, 2) by hydrocracking at 50 atm followed by catalytic cracking of unconverted part of the charge to the hydrocracker, and 3) catalytic cracking of vacuum gas oil + hydrotreating of products.

2. An economic evaluation was given of 2-stage hydrocracking of vacuum gas oil at pressures of 150 atm. and catalytic cracking + hydro-

treating of the same charge stock. (Charge - 1 million tons).

The basic conclusions indicated that in the first series of processes, the combination of hydrocracking and cat cracking was most economical and produced the maximum yield of light products (74%). In the second (high-pressure hydrocracking), the hydrocracking provided a higher yield of light products, but over-all was 36% to 47% more expensive then catalytic cracking + hydrotreating. The Soviet author estimated that such a unit (high pressure) built in the USSR would cost 22 million rubles whereas in the U.S. the capital investment would be about 8 million rubles.

A process called "thermal contact cracking (TCC)" was developed in the mid 1960's. It reportedly has sufficient flexibility to alter product output from a given feedstock and to produce coke. One commercial unit has been installed and plans call for units with capacities up to 900,000 tons/year to be built. TCC apparently can be used to upgrade heavy residuals to provide a charge to catalytic cracking.

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Refining Developments in Eastern Europe

In 1970 the Communist countries of Eastern Europe* will process some 55 million tons of crude oil in their refineries. (See Table 1 for crude oil charge capacities, by country.) About 16 million tons of this total will be produced in these countries and 39 million tons will be imported. Imports from the USSR will approximate 34 million tons and about 5 million tons will be obtained from the Free World (Middle East and North Africa). The estimated capacity of catalytic secondary processing units in Eastern Europe is less than 15 million tons, or only about one-fourth of total crude charge capacity. Fluid catalytic cracking capacity in these countries amounts to approximately 2.4 million tons per year. Only Romania and Poland have catalytic cracking facilities. The Plock refinery in Poland has a Soviet-built unit with a capacity of 750,000 ~~million~~ tons per year and Romania has a US-built unit with a capacity of 1.1 million tons per year (at the Brazi refinery) and 2 small Soviet-built plants with a total capacity of 500,000 tons per year (at the Gheorghe Gheorghiu Dej refinery).

Available data on plans for 1975 indicate that total crude oil charge capacity in Eastern Europe will approximate 90 million tons and total crude oil supply should be at about that level. Imports

* Includes Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania.

of crude oil should amount to about 72 million tons, of which 57 million will come from the USSR and 15 million from the Free World. Most of these countries plan to install more secondary processing facilities in new refineries that are to be built. There is considerable interest in employing US technology and equipment in the new refineries, especially for catalytic cracking and hydrocracking units. Details are incomplete but the total capacity of catalytic and hydrocracking units should reach some 9 million tons in 1975. (See Table 2).

During the period 1976-80, expansion of refining capacity will continue and may reach a level of 120-130 million tons per year by 1980. Indigenous crude oil production in Eastern Europe probably will not exceed 20 million tons; imports will reach more than 100 million tons of which three-fourths may be provided by the USSR. As the demands for higher quality products increase, there will be a greater effort to install secondary processing facilities, but the type and capacity of each cannot be quantified.

Table 1

Estimated Crude Oil Charge Capacity in Eastern Europe

Million metric tons

Country	1970	1975	1980
Bulgaria	6	13-14	20- 23
Czechoslovakia	10	17-18	22- 25
East Germany	10	15	20
Hungary	6	9-10	14- 15
Poland	7.5	14-15	22
Romania	16	19-20	24- 25
Total	55.5	87-92	122-130

Δ 35   Δ 35

700,000 B/D ↓ 35-700 million   700,000 B/D ↓ 35-700 million

USSR capacity	300	375	450
Cat cracking	18-20		

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Table 2

Estimated Capacities of Secondary Processing (Catalytic) Facilities in Eastern Europe

Thousand metric tons

Country	1970	1975	1980
Bulgaria	300 - CR 300 - HT	1,200 - CR 1,300 - HT	NA
Czechoslovakia	500 - CR 850 - HT 120 - Alk	1,000 - CC 1,300 - CR 1,800 - HT 120 - Alk	3,000 - CC 2,000 - CR 3,000 - HT NA - Alk
East Germany	1,000 - CR 800 - HT	1,000 - CC (or HC) 1,500 - CR NA - HT	NA
Hungary	600 - CR 1,000 - HT	1,000 - CC (or HC) 900 - CR 1,000 - HT	NA
Poland	750 - CC 600 - CR 1,700 - HT 450 - DC	2,300 - CC 1,000 - HC 1,800 - CR 2,000 - HT NA - DC	NA
Romania	1,600 - CC 1,900 - CR 1,200 - HT 800 - DC	1,600 - CC x/ 1,000 - HC NA - CR NA - HT NA - DC	NA
Total			
Cat. Cracking (CC)	2,350	6,900	
Cat. Reforming (CR)	4,900	6,700	
Hydrogen Treating (HT)	5,850	6,100	NA
Delayed Coking (DC)	1,250	NA	
Alkylation (Alk)	120	NA	
Hydrocracking (HC)	0	2,000	
	14,470	NA	

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Implications of US Sales of Catalytic Cracking Units to Eastern Europe

Polish Request

The apparent increasing demand for gasoline in the Polish economy has prompted the desire for catalytic cracking, the most useful process for increasing the yield of gasoline from crude oil. In 1969, Poland consumed about 2.3 million tons of gasoline, about one-third of the total apparent consumption of almost 7 million tons of oil products. Of the total consumption of gasoline, it is estimated that net imports amounted to about 800,000 tons. (See tabulation below) The acquisition of a catalytic cracking unit, with a capacity of 1.5 million tons/year (32,000 B/SD), would be instrumental in increasing the yield of gasoline from imported crude oil and in reducing imports of this product.

Estimated Oil Supply in Poland, 1969
(Thousand Metric Tons)

	Output	Imports	Exports	Apparent Consumption
Gasoline	1,500	900	100	2,300
Kerosine	120	20	0	140
Diesel fuel	1,940	700	500	2,140
Lube oil	180	20	0	200
Resid. fuel oil	2,050	550	1,000	1,600
Other	430	210	100	540
Total	6,220	2,400	1,700	6,920

Poland has expressed an interest in purchasing from UOP a fluid catalytic cracking unit with an annual capacity of 1.5 million tons (32,000 B/SD), to operate on Romashkino gas oil with a 75% conversion, and to produce 25-26,000 B/SD of gasoline with an octane number of at least 90. According to UOP technicians the catalytic cracker of a comparable capacity built by Soviet experts might produce more total gasoline than a US-built unit, and the resultant product would be as good, provided that catalysts of western origin were used. The UOP personnel estimated that capital investment for a US-built catalytic cracker of the proposed capacity might be $1\frac{1}{2}$ to 2 times less than for a comparable Soviet-built unit, because of the larger reactor and regenerator and generally more iron in the Soviet plant. UOP experts also suggested that direct operating costs of a US-built catalytic cracker would be about half of the Soviet-built unit, although total operating costs might be only slightly less for the UOP unit.

The total cost of the proposed cat. cracker and ancillary facilities installed in the Plock refinery (including catalyst costs and royalties) was estimated at about $15 million by UOP technicians. According to Soviet sources, in 1969 the capital construction costs of a catalytic cracker with a capacity of 1 million tons/year was 5.2 million rubles (about $5.8 million at the official rate of exchange). However, it is difficult to make a quantitative assessment of the comparable costs for building Soviet or US catalytic cracking units in Eastern Europe because of the lack of Soviet data on what is included in their capital outlays and because of the unknown ruble/dollar ratio in prices of equipment, construction costs, labor costs, etc.

Future Catalytic Cracking Needs in Eastern Europe

During the next 5 years (1971-75), plans call for total crude oil charge capacity in Eastern Europe to increase by about 35 million tons (700,000 B/D). Included in this expansion will be a sizable effort to add secondary refining facilities for increasing the flexibility of refinery operations and upgrading the quality of the products produced. From available data on plans it appears that Eastern Europe will seek to obtain at least 6 fluid catalytic cracking units, each with a capacity of at least 1 million tons/year (21,000 B/D). The total cost of refinery expansion during the 5-year period might approximate $500 million (assuming a cost of $700 per barrel of daily feed capacity). The cost of the 6 catalytic cracking units, if purchased in the US, would probably range from $70 to 90 million, based on charges estimated by UOP for the unit requested by Poland. The desire for the latest western cracking technology (US) may outweigh the reservations by these countries in spending scarce foreign exchange for such equipment. If Soviet cracking units were installed in Eastern Europe, they could be purchased with goods via a barter deal, with no expenditure of hard currency. However, after Polish and Romanian experience with Soviet equipment, East European purchases of such equipment may be made only if US technology is denied to them.

The sale of 6 catalytic cracking units to Eastern Europe during the next 5 years would have a minimal effect on product output in Eastern Europe. There would be an overall increase in the yield of gasoline and a decline in fuel oil yields, but these changes would be reasonable and normal to meet increasing and changing demands for civil (and military) consumption. (See attached table).

During 1976-80 a further expansion of 35 million tons of crude oil charge capacity in Eastern Europe is foreseen. It is anticipated that additional catalytic cracking units (and hydrocracking units) -- perhaps 6 to 8 -- will be required to meet future needs of the area.

Catalytic Cracking Developments in the USSR

Catalytic cracking capacity in the USSR is estimated at about 400,000 B/D (20 million tons/year), or about 6.5% of total crude oil charge capacity. By comparison, catalytic cracking capacity in the US is almost 6,000,000 B/D, equivalent to more than 40% of crude charge capacity. The yield of gasoline on crude in the US is about 51% because of the extensive use of the automobile. In the USSR, however, where the demand for automotive gasoline is small, but growing, the gasoline yield approximates 17%.

In its own program of building secondary refining facilities, the USSR has failed miserably during the past 7-8 years. Soviet planners have complained bitterly about the chronic underfulfillment of construction schedules and the operation of the units at less-than-designed capacity even after their delayed completion. New capacities for catalytic cracking, catalytic reforming and coking are not being put on stream as needed, in view of increasing needs for higher quality products. A high-level Soviet refining official recently stated that if corrective measures are not taken quickly, the refining situation would become critical during 1971-72.

Soviet experience in construction of catalytic cracking units has proceeded slowly with the use of standard designs, first with a capacity of 10,000 B/D, then with 15,000 B/D and fairly recently with a capacity of 24,000 B/D. From observation and from Soviet data, the sizes of reactors and regenerators are considerably larger than used in US units, the catalysts employed are not as good and catalyst losses are larger, and average efficiency of operation is about 85%, compared to 94% in US units. In addition to the problems mentioned above, the USSR has, in the last few years, underfulfilled goals for production of refinery equipment and has increased imports of such equipment, both from the Free World and from Eastern Europe. It is quite possible that the USSR may be unable to supply the catalytic cracking units needed by Eastern Europe during the next few years and meet its own refinery construction schedules from available resources.

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Possible Yields of Petroleum Products in Eastern Europe, 1975*

	Million Tons	Percent
Charge to refineries	85	100
Gasoline	20.4	24
Kerosine	2.6	3
Diesel fuel	27.2	32
Lubricating oils	2.6	3
Residual fuel oil	21.2	25
Other	4.2	5
Gas and loss	6.8	8

*Assuming addition of 6 catalytic cracking units with a total charge capacity of 9 million tons/year.

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